Use of myocardial perfusion imaging after coronary revascularization

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INTRODUCTION — Stress myocardial perfusion imaging (MPI) is an important tool in the evaluation and assessment of patients prior to coronary revascularization. In addition, stress MPI is useful in evaluating patients for recurrent ischemia after revascularization by either coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI).

The role of MPI after coronary revascularization is based upon two observations:

- The frequent occurrence of coronary restenosis after PCI and coronary graft or progressive native coronary stenosis after CABG
- The possible presence of incomplete revascularization, since certain lesions or arteries may not be amenable to PCI or CABG

The following discussion focuses on evidence from clinical trials regarding the appropriate use of stress MPI in patients who have undergone a revascularization procedure. Current guidelines and how they can be translated into clinical practice will also be reviewed. The use of myocardial perfusion imaging prior to revascularization to detect hibernating myocardium (ie, myocardial viability) and in the diagnosis, evaluation, and prognosis of coronary heart disease are discussed separately. (See "Assessment of myocardial viability by nuclear imaging in coronary heart disease", see "Exercise myocardial perfusion imaging in the diagnosis and risk stratification of coronary heart disease", and see "Risk stratification for future cardiac events after myocardial infarction with myocardial perfusion imaging").

EVALUATION OF PATIENTS AFTER CABG

Indications — The long-term effectiveness of CABG is limited by graft stenosis, which is primarily limited to saphenous vein grafts, and progression of native disease.

Indications for stress MPI after CABG are [1]:

- Documentation of intraoperative cardiac injury
- Documentation of improvement in perfusion or function
- Identification of graft disease and stenosis
- Prediction of subsequent cardiac events (risk stratification and prognosis)

The primary value of stress MPI lies in the ability to identify graft disease or occlusion. While internal mammary artery grafts have a high patency rate (88 percent and 83 percent after 5 and 10 years respectively), saphenous venous graft occlusion occurs in approximately 10 percent of patients during the first year with subsequent 5 and 10 year patency rates of 74 percent and 41 percent respectively (show figure 1) [2,3]. (See "Long-term outcome after coronary artery bypass graft surgery").

Diagnostic accuracy — Stress MPI can accurately detect graft stenosis, even in patients with atypical symptoms, and can effectively localize the stenosis, especially if gated SPECT (single photon emission computed tomography) imaging is performed [4-7]. In one study, for example, thallium-201 SPECT imaging was performed in 50 patients at 51 months after surgery [6]. All patients had chest pain, although the symptoms were atypical in 40 percent. Compared to exercise ECG testing, stress MPI had significantly greater sensitivity (80 versus 31 percent) and accuracy (82 versus 50 percent) with comparable specificity (87 versus 93 percent).

The sensitivity and specificity of SPECT for the detection of graft stenosis did not differ from previous reports with planar imaging [7]. However, the sensitivity for individual diseased vascular territories was substantially higher with gated SPECT stress MPI: 82 percent for the left anterior descending artery territory, 92 percent for the right coronary artery territory, and 75 percent for the left circumflex artery territory [6]. In contrast, localization of the occluded graft was correct in only 61 percent of patients with planar imaging [7].

In conclusion, the main indication for stress MPI after CABG is to identify areas of ischemic myocardium caused mainly by saphenous venous graft occlusion. Gated SPECT imaging adds incrementally to the diagnostic accuracy of MPI, and assists in the localization of the stenotic lesion.

Time after CABG — The evaluation of post-CABG patients with stress MPI depends upon the presence or absence of symptoms and the time from the surgical procedure.

Within two years — Significant reversible perfusion defects suggestive of ischemia occur in about one-quarter of patients by one year after CABG; not all of these patients have angina. These observations are illustrated by two studies:

- In one report, 411 patients (34 percent asymptomatic, 66 percent with chest pain or dyspnea, 79 percent with internal mammary graft) underwent exercise thallium-201 MPI within two years after CABG (mean eleven months) [11]. More than 50 percent of patients had reversible defects on MPI, but only 26 percent had more than three segments of myocardium involved, and only 12 percent had evidence of redistribution proximal to a graft insertion site. At five years, the survival rate free of cardiac death or MI was 87 percent overall; for patients with 0, 1 to 3, 4 to 6, and greater than or equal to7 ischemic segments on MPI, the rates were 92, 89, 85, and 72 percent, respectively (show figure 2). The findings were not stratified according to whether or not the patients had symptoms prior to the imaging study; this is a major limitation since all symptomatic patients should be tested.

- In an analysis from the EAST trial, 336 patients who had been randomly assigned to either PCI or CABG (90 percent with internal mammary graft) underwent thallium-201 SPECT MPI with exercise one year after their revascularization procedure, regardless of symptoms [12]. Among those who underwent CABG, 19 (11 percent) reported angina at the time of testing; however, 47 (27 percent) had a large or moderate-sized reversible defect on MPI. At two years, survival free of cardiac death or MI in patients with large or moderate-sized defects was significantly lower than in those without such findings (88 versus 96 percent).

Five years — As noted above, saphenous vein graft patency begins to decline rapidly after five years, while patency rates for arterial grafts remain high (show figure 1) [2,3]. In patients with saphenous vein grafts who are late (>5 years) post-CABG, irrespective of symptoms, myocardial perfusion SPECT has been an effective method for risk stratification, prognosis, and determination of disease progression [13-16]. These relationships can be illustrated by the following observations.

One report evaluated 294 patients greater than or equal to5 years post-CABG, 85 percent of whom received a saphenous vein graft [13]. During the 31-month follow up, the event rate (death or nonfatal myocardial infarction) was 14 percent. Two exercise scintigraphic variables, the 201-Tl reversibility score, which was a global measure of ischemic index, and the presence of increased lung uptake, which is a measure of exercise-induced left ventricular dysfunction, added significant prognostic information over clinical and exercise data. When these variables were present, the odds of a cardiac event increased by 80 and 10 percent, respectively.

A later and larger study included 1765 patients who underwent dual-isotope SPECT MPI 7.1 ± 5.0 years post-CABG; 1544 were followed for at least one year after testing (mean two years) [16]. Data were not available concerning the type of graft used. A total of 53 cardiac deaths occurred. There was a significant increase in annual death rates as a function of summed stress score for ischemia, which was equal to the total of all segmental scores added together at stress.

Stress MPI provided important prognostic information in patients more than five years post-CABG, irrespective of symptoms, and in symptomatic patients who were less than or equal to5 years post-CABG. In both groups, a moderate or severely abnormal summed stress score predicted a significantly higher annual cardiac death rate (2.1 and 3.1 percent, respectively) (show figure 3). Asymptomatic patients who were less than or equal to5 years post-CABG had a lower cardiac death rate (1.3 percent per year) and did not benefit from stress MPI. Cardiac mortality was very low in patients with a normal MPI (0 and 0.7 percent per year at less than or equal to5 and more than five years post-CABG, respectively.

Recommendations — The 2002 ACC/AHA guideline for exercise testing [8,9] and the 1995 guideline for the clinical use of radionuclide imaging [10] argue against routine testing of asymptomatic patients after CABG. They do recommend exercise testing for patients with recurrent ischemic symptoms and for selected, high-risk, symptom-free patients (show table 1). Among patients who undergo testing, MPI was recommended in those who have an abnormal ECG response to exercise or resting ECG changes that preclude identification of ischemia during exercise. (See "ACC/AHA guidelines for exercise testing: Special groups: Women, asymptomatic individuals and postrevascularization patients" and see "ACC/AHA guidelines for clinical use of cardiac radionuclide imaging: Clinical uses of radionuclide imaging").

However, there is strong evidence, as noted above, that stress MPI is an effective means of risk stratification and provides guidance to appropriate therapy in patients more than five years post-CABG with or without ischemic symptoms (show algorithm 1). Patients with a moderate to severe perfusion defect and reversibility on stress MPI should undergo coronary angiography [16].

EVALUATION OF PATIENTS AFTER PCI

Indications — The important role of percutaneous transluminal coronary angioplasty (PTCA), now mostly with stent placement, in patients with single or multivessel disease has created a necessity for early detection of restenosis. Angiographic restenosis occurs in 30 to 40 percent of patients treated with PTCA and 20 to 30 percent of those treated with bare metal stents (show figure 4) [17-19]. However, clinical restenosis is present in only about one-half of these patients, primarily in lesions with more than 70 percent diameter stenosis [19,20]. (See "Restenosis after percutaneous transluminal coronary angioplasty" and see "Intracoronary stent restenosis").

The availability of drug-eluting stents, such as the sirolimus stent, should markedly reduce the incidence of in-stent restenosis (show figure 5) [21,22]. Thus, the data presented below may not be as applicable to patients treated with the newer stents. (See "Newer intracoronary stents").

Diagnostic accuracy — Several studies have documented the superiority of stress MPI, compared to stress ECG testing alone, for identifying restenosis after PTCA with or without stent placement [23-27].

The following results illustrate the range of findings. However, their applicability to current practice is uncertain since the great majority of patients undergo stenting (not PTCA alone) and the incidence of in-stent restenosis should fall markedly with the drug-eluting stents.

- One of the first studies evaluated 30 patients with single vessel disease who underwent successful PTCA; significant improvement in perfusion was noted in 28 [23]. Only those patients with an abnormal MPI at six months after angioplasty had evidence of restenosis.
- Another report compared exercise ECG testing with and without MPI in 116 patients, over one-half of whom had multivessel PCI [24]. Using angiography as the gold standard, MPI was associated with a significant increase in sensitivity (93 versus 53 percent with exercise ECG testing alone) and a trend toward an increase in specificity (77 versus 64 percent). Similar benefits from exercise MPI were noted in another series [25].
- Stress MPI produces similar results after stenting [26,27]. This was illustrated in a series of 82 patients who underwent technetium-99m stress/thallium-201 rest SPECT MPI and coronary angiography 200 days after stent placement [26]. The vascular territories of 909 coronary arteries were examined. The sensitivity and specificity of MPI for detecting restenosis were 79 and 78 percent overall and 100 and 82 percent in patients without a prior infarction.

Time after PCI

Within one week — A particular concern with early testing after PTCA is that reversible defects consistent with ischemia have been found in the distribution of the dilated vessel in 18 to 47 percent of patients during the first week [28-32]. Resolution of these perfusion defects without revascularization was noted during subsequent stress testing in one report, suggesting that the findings could represent a transient high false positive rate [32]. In contrast, others have shown that early stress MPI after PTCA is accurate, usually confirms the success of the procedure, that perfusion defects can often be explained by an causative abnormality, and that such defects predict late restenosis [29-31].

Most of these studies were performed during the era of PTCA alone without the benefit of stent placement. PTCA may have contributed to the positive tests by inducing early postprocedural vasoconstriction. In addition, MPI was performed with planar imaging, which is known to have a high incidence of attenuation artifacts. With the advent of stenting and the development of tomographic imaging techniques, it is no longer clear that the accuracy of early imaging after PCI poses a concern.

More than three months — The use of stress MPI in risk stratification more than three months after PCI has been evaluated for PTCA with or without stenting. In a report of 211 patients treated with PTCA, exercise thallium-201 MPI was performed two years after intervention; one-third of patients were asymptomatic at the time of testing [33]. Half of patients had at least one reversible segment on MPI. At seven years follow-up, there were eight cardiac deaths and 11 nonfatal MIs. A summed stress score, based on the total number of underperfused segments and the severity of the decrease in perfusion, was significantly correlated with the combined endpoint of death or nonfatal MI.

Stress MPI has also been performed late after coronary stent placement. In one study, 152 patients were evaluated with stress thallium-201 SPECT MPI five months after stenting [34]. Ischemia (at least two contiguous segments with reversible defects) was detected in 47 (31 percent). At 40 months follow-up, major cardiac events (death or MI) had occurred significantly more often among the patients who had ischemia on stress MPI compared to those who did not (3 versus 28 percent) (show figure 6).

Recommendations — The 2002 ACC/AHA guideline for exercise testing [8,9] and the 1995 guideline for the clinical use of radionuclide imaging [10] argue against routine testing of asymptomatic patients after PCI. They do recommend exercise testing for patients with recurrent ischemic symptoms and for selected, high-risk, symptom-free patients (show table 1). Among patients who undergo testing, MPI was recommended in those who have an abnormal ECG response to exercise or resting ECG changes that preclude identification of ischemia during exercise. (See "ACC/AHA guidelines for exercise testing: Special groups: Women, asymptomatic individuals and postrevascularization patients" and see "ACC/AHA guidelines for clinical use of cardiac radionuclide imaging: Clinical uses of radionuclide imaging").

We recommend the following approach (show algorithm 2):

- Patients with an uncomplicated, angiographically successful PCI without recurrence of symptoms probably do not need routine stress MPI. Such patients often undergo exercise ECG testing at four to six weeks for reassurance of the patient. Stress MPI can be performed if the exercise ECG is abnormal.

- Asymptomatic patients should be studied if they are at high risk after PCI. High risk features include decreased left ventricular function, multivessel disease, proximal left anterior descending disease, previous sudden cardiac death, diabetes mellitus, hazardous occupations, and suboptimal PCI results [8,9].

The proper timing of stress MPI after PCI in high-risk asymptomatic patients is uncertain. Based on existing knowledge regarding the peak incidence of subacute thrombosis (less than four weeks) [35] and clinical in-stent restenosis (three to twelve months) [36], we recommend a time frame of four to six weeks post intervention [10].

- Patients with symptoms typical of ischemia less than six months after PCI should undergo coronary angiography as a first step, unless contraindicated. If angina occurs later (more than six months post-PCI), stress MPI can be used to assess the degree and area of ischemia, since progression of native coronary disease rather than in-stent restenosis is more likely. (See "Use of intracoronary stents for the prevention of restenosis").

- Stress MPI is recommended at any time in patients who develop atypical symptoms after PCI to assess whether these symptoms represent ischemia.

As noted above, the advent of coated stents such as the sirolimus stent should reduce the incidence of restenosis substantially. The exact role of stress MPI after the use of these newer stents remains to be determined. (See "Newer intracoronary stents").

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